



ICCE 2010

NUMERICAL SIMULATION OF WATER IMPACT INVOLVING THREE DIMENSIONAL RIGID BODIES OF ARBITRARY SHAPE

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Objectives

- Development of a 3D flow solver based on the Euler equations using a Riemann-based finite volume method and Cartesian cut cell meshes for simulating water impact problems involving arbitrarily complex moving rigid bodies.

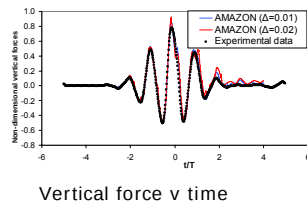
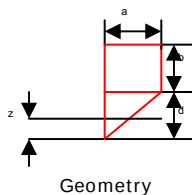
Methods

- Incompressible Navier-Stokes solver — Based on an artificial compressibility method.
- Surface-capturing method that treats the free surface as a contact discontinuity in the density field so no special procedures are required to track the free surface.
- Fully two phase approach which solves in both the air and water fluid regions.
- Cartesian cut cell Method
 - flexibility for dealing with complex moving geometries
 - no requirement to re-mesh globally: only requires updates locally at cells on the background Cartesian mesh that are actually cut by the moving boundary contour.

Results

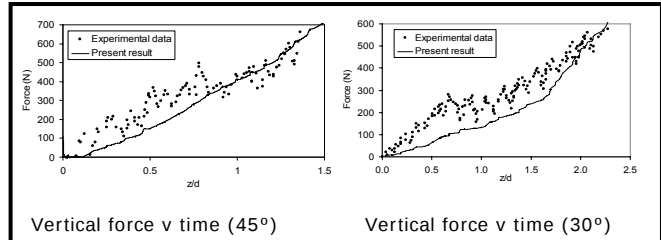
1. Oscillating cone validation

- Vertical position of a cone $d(t)$ follows the form of a Gaussian wave packet: $d(t) = A \sum_{n=1}^N Z(\omega_n) \cos\left[\omega_n(t-t_0) - \frac{h\pi}{2}\right] \Delta\omega_n$
- Experiments conducted by K. Drake *et al.* (2009).
- Test case: $A=50\text{mm}$, $m=9$ and cone dead-rise angle of 45° .
- Tank: $2.0\text{m} \times 1.6\text{m}$, the water depth: $h=1.02\text{m}$ and the initial draught of the cone is $z=0.148\text{m}$.
- Dimensions: $a=0.228\text{m}$, $d=0.2281\text{m}$, $b=0.05\text{m}$
- CPU time on coarse mesh ($dx=dy=0.02\text{m}$) 15 hours
- CPU time on fine mesh ($dx=dy=0.01\text{m}$) 41 hours



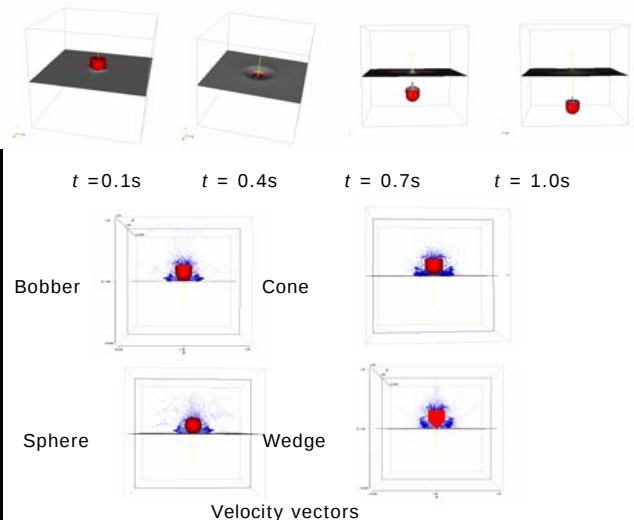
2. Water entry of a 3D rigid wedge validation

- Body moves vertically downwards towards an initially still water surface at a velocity $V=1.19\text{m/s}$ (45° dead-rise angle) and velocity $V=0.72\text{m/s}$ (30° dead-rise angle).
- Experimental data (Tveitnes *et al.* 2008).
- Tank: $2.0\text{m} \times 0.4\text{m} \times 2.0\text{m}$ and the water depth: $h=1.0\text{m}$.
- Uniform mesh: $80 \times 16 \times 80 = 102,400$ ($dx=dy=dz=0.025\text{m}$).
- Dimensions: breadth=0.6m, length=0.3m, height=0.3m.



3. Water entry of various rigid 3D bodies

- Input Body moves vertically toward an initially still water surface at $V=1\text{m/s}$.
- $R=0.15\text{m}$, height=0.15m.
- Tank: $2.0\text{m} \times 0.15\text{m} \times 2.0\text{m}$ and water depth: $h=1.0\text{m}$.



Conclusion

- Validations included forced oscillation of a cone and water entry of a 3D rigid wedge.
- AMAZON-SC3D has been successfully implemented for various slamming cases involving the Manchester Bobber; cone; sphere and wedge.

References

- Drake, K., Eatock Taylor, R., Taylor, P. and Bai, W. (2009). "On the hydrodynamics of bobbing cones." accepted.
- Tveitnes T., Fairlie-Clarke A.C., Varyani K. (2008). "An experimental investigation into the constant velocity water entry of wedge-shape sections," *J. Ocean Eng.* 35: 1463-1478.
- Hu Z.Z., Causon D.M., Mingham C.G., Qian L. (2009). "Numerical wave tank study of a wave energy converter in heave." Proceedings 19th ISOPE conference, Osaka, Japan.